NATIONAL URANIUM TAILINGS PROGRAM

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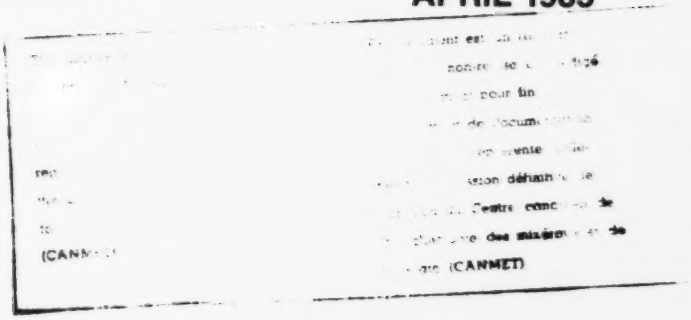

MICROMEDIA

SUMMARY

As a result of a year-long study undertaken by a group of experts from government, industry and the universities, the decision was taken by the Federal Government to launch an R&D program into the long-term effects of uranium mill tailings on the environment. To this end, the National Uranium Tailings Program (NUTP) of CANMET has been funded to the extent of $8.5 million allocated over a period of five years.

The main objective of the NUTP is to provide a scientifically credible information base that will assist government regulatory agencies and industry in making a knowledgeable decision and in establishing criteria for the long-term protection of the environment and human health. The information base, among other things, describes the chemical and physical processes involving tailings constituents, and their movement along pathways from the tailings into the biosphere.

The NUTP's activities, which have been entirely contracted out, have included research into the processes involved in the behaviour and movement of contaminants from tailings, field sampling and measurements, chemical analyses, and predictive modelling.

This report summarizes the Program's progress to March 1985. The discussion includes the history, philosophy, focus and approach, progress and current status of the major projects in the Program. A typical result from the preliminary system-modelling work is included to illustrate the type of predictive information to be expected from the Program.

SOMMAIRE

À la suite d'une étude d'un an, le Groupe national de planification technique de la recherche sur les résidus d'uranium a conclu qu'il n'existait pas suffisamment de données scientifiques pour prévoir avec assez de certitude les répercussions à long terme des résidus d'uranium. Donc, en 1982, le gouvernement du Canada a annoncé la mise en oeuvre du Programme national de recherche sur les résidus d'uranium. Dans le cadre de ce programme quinquennal de recherche, 8.5 millions de dollars seront consacrés à l'étude et à la prévision des effets à long terme sur l'environnement des résidus des mines d'uranium et de leurs effluents.

Le programme a principalement pour but de constituer une banque de données digne de foi d'un point de vue scientifique qui pourra aider les organismes gouvernementaux de réglementation et l'industrie minière à élaborer des stratégies de gestion à long terme pour la protection du public et de l'environnement.

Les activités du programme, réalisées au moyen de contrats, comprenaient des travaux de recherche sur les processus relatifs au comportement et au mouvement des contaminants provenant des résidus, des échantillonnages et des mesures sur le terrain, ainsi que des analyses chimiques et la création de modèles.

Ce rapport est un sommaire du progrès du programme jusqu'à la fin mars 1985. L'histoire, la philosophie, le but, le progrès et l'état actuel des projets majeurs du programme, ainsi que le résultat typique du modèle préliminaire servant à illustrer le genre d'information prévisoire que l'on peut obtenir de ce programme, sont inclus dans le présent rapport.

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1. INTRODUCTION

The National Uranium Tailings Program (NUTP) is part of the Minerals and Earth Sciences Program of Energy, Mines and Resources Canada and, in particular, the Mineral and Energy Technology activity. It has a distinct management and financial structure within the Mineral Sciences Laboratories of the Canada Centre for Mineral and Energy Technology (CANMET).

The Minister of State for Mines announced the NUTP in September 1982 and it received Treasury Board approval in November 1982 when approximately $8.5 million was allocated over a period of five years. While basic funding was approved in late 1982, Program staffing was not complete until June 1983. Thus, the Program has been functioning for effectively two fiscal years. The work of the Program is totally contracted out, mainly to the private sector.

This report summarizes Program progress to March 1985. The discussion includes the history, philosophy, focus, approach, progress and current status of the major projects in the Program. A typical result from the preliminary system modelling is included to illustrate the type of predictive information to be expected from the Program.

2. HISTORICAL SETTING

By 1982 when the Program was announced, there were about 130 million tonnes of uranium tailings in Canada with about 100 million in Ontario, 30 million in Saskatchewan and 1 million in the Northwest Territories. This number was expected to double by the year 2000. While these numbers are small compared with mine tailings in general, uranium tailings have a special significance because of the small quantities of radioactive materials they contain.

Over the years, considerable work on the behaviour of Canadian uranium mill tailings has been done by many different organizations with different needs or questions in mind at the time that the work was done. In view of the concerns expressed at several public hearings and elsewhere in the late 1970's on the potential problems of uranium mill tailings, CANMET considered launching an integrated research and development program for the long-term management of Canadian tailings. A meeting was convened of those in government and industry involved in, or sponsoring, research on uranium tailings. As a result, the National Technical Planning Group (NTPG), a group of experts on uranium mining and processing, was appointed by CANMET. Their purpose was to review present activities and to propose a research program to define the nature and extent of potential problems posed by uranium tailings.

The group studied present practices of tailings management, the condition of abandoned tailings, the state of knowledge and understanding about tailings, and the measures adopted by government agencies to regulate tailings disposal. At the end of the study (1), the group concluded that:

- although active management schemes are used to maintain the releases from inactive tailings within regulatory limits, the steps which must be taken for the safe total abandonment of uranium tailings have not yet been demonstrated. Insufficient is known about the long-term behaviour of the tailings to state confidently whether or not there would be a problem. The task, therefore, is to devise appropriate abandonment techniques based on a better understanding of the mechanisms of chemical constituent transport and dispersion.

The NTPG then went on to recommend that:

a) The Federal Government and the governments of Ontario and Saskatchewan jointly establish a uranium tailings research and development program with a major review to be conducted at the end of three years to decide on the need for and nature of a continuation.

b) An independent National Tailings Program Office be established in Ottawa to manage the program.

c) The tailings R&D program consist of three components:
   i) Measurements
   ii) Modelling
   iii) Disposal Technology

A number of objectives were suggested for the Program, the essence of them being to pull together the previous work on Canadian uranium tailings, to fund additional work where significant gaps were found in understanding or in essential data and to develop a capability to predict the long-term effects of tailings, such that decisions could be made on acceptable close-out procedures. In addition, the NTPG recommended that three tailings areas be extensively studied and that a national uranium waste management database be developed. The cost estimate for the recommended Program was $18.6 million for the first three years. The Program was to be reviewed at the end of the three years and decisions made on the need for, nature and funding of additional work.

The NTPG did not envisage that the recommended three-year Program would provide definitive answers for the ultimate safe disposal of uranium tailings. However, it did believe that the Program would be instrumental in determining the nature and extent of the problem of uranium tailings disposal and would provide a solid information base for decisions on future research on tailings.

The provinces declined to join the Program, but the Federal Government decided to proceed because of the apparent need for the work. The funds actually allocated were substantially reduced (from $18.6 to $8.5 million) because of the non-participation of the provinces. Also, the Program duration was increased from three to five years to allow for the practical aspects of the Program management plan chosen. Although the provinces declined to participate directly, they recognized the need for research and they have supported the work of the Program in many practical ways.

The questions commonly raised about uranium tailings all deal with their specific behaviour over the long-term and the potential movement of contaminants through the environment to man. What these questions reduce to is a question of safety and how our regulatory agencies will decide, on behalf of society, how safe is safe enough. Thus, the question is really one of safety assessment or risk management on behalf of society. Making these assessments requires, where possible, quantitative measures of safety, a term which is difficult enough to define, let alone quantify. Thus, the processes of safety decision making must be examined first before an appropriate research program can be defined.

3. SAFETY ASSESSMENT

3.1 SAFETY - WHAT IS IT?

"Safety Assessment", what it is, who should do it, and what information is needed is often a confusing and potentially acrimonious process because of the complexity and diversity of the concepts, issues and points of view involved. A useful clarification is achieved by defining "safety" as a "judgement of the acceptability of risk" and risk, in turn, as a measure of the probability and severity of undesirable consequences for any proposed activity (2). Simply put, an object or activity is safe if its risks are judged to be acceptable.

The word "judgement" implies that safety is a notion in the mind and recognizes that it is not an absolute quantity. It is in the mind, not as a figment of the imagination, because it is very real, but as a personal perception or feeling.

The two words, risk and acceptability, cleanly divide an issue into two distinct and very different parts. "Risk" is a relatively objective, although probabilistic, concept. One can usually put a number on risk within certain limits and it can be reduced by design within certain practicable limits. The scientist is generally well trained to study and comment upon risk because of the objective quantities involved. "Acceptability", however, is subjective and a matter of individual, personal and social value judgement. The scientist is generally no better suited to judge acceptability than anyone else who has access to the relevant facts in a form that he or she can understand. The distinction between the objective nature of risk and the subjective nature of acceptability is very important and failure to appreciate this difference by both scientists and the public is frequently the source of the confusion mentioned above.

Making individual and collective judgements on the acceptability of the risk associated with a particular activity requires information on three major aspects: benefits expected, risks involved and the costs of risk reduction. These are shown schematically in Figure 1.

The need for information on benefits and risks is fairly clear. For example, if there is no benefit, then why accept any risk if there is a choice? The need for information on the costs of risk reduction arises through the International Commission on Radiological Protection (ICRP) system of dose limitation. Their recommendations are that, for an activity to proceed which will lead to exposure:

a) there must be a benefit to society,
b) exposures should not exceed certain limits, and
c) exposures should be kept as low as reasonably achievable, economic and social factors being taken into account.

The ICRP is an independent body of radiation health experts. Their work is well respected and forms the basis for much of the radiation protection regulation around the world, including Canada.

The principle of optimization implied in (c) indicates clearly that just staying under the limits (principle (b)) is not sufficient. Making decisions as to the extent to which (c), the As Low As Reasonably Achievable (ALARA) principle, has been achieved requires information on many things. The major variable in these decisions is the choice of disposal technology. Each technology option incurs certain costs and some options are more effective than others in reducing doses and/or impacts on the environment. Thus one element in decision making for a particular situation is the relative cost-effectiveness of the feasible disposal technology options, since it usually is not worth spending large incremental sums for only small gains. (On a larger scale, of course, if benefits similar to those of the overall project can be achieved by an alternative route, then risks and costs of risk reduction for that route must also be assessed if a relative judgement is to be made.)

3.2 PROGRAM FOCUS

Assessing the benefits and more general safety issues of uranium mining and the Nuclear Fuel Cycle is beyond the scope of this program which is limited to uranium mill tailings. The Program and the modelling work in particular focus on quantifying the risks associated with uranium tailings including the cost-effectiveness of the various ways of reducing risks. The ideal situation is to be able to dispose of tailings in such a way that perpetual care of any sort is not required. In essence, the goal is to provide the fundamental understanding and the tools to facilitate the quantitative assessment of the degree to which a "walkaway" situation can be achieved. The needs of three constituencies, i.e. the regulatory authorities, the mining industry and the public are being considered as the work proceeds.

The principal risk considered is that to the health of man from the potential release of radioactive and non-radioactive chemical contaminants from tailings facilities. Other ecosystem or aesthetic effects may be quite important in specific situations and certainly require consideration in any overall assessment. While the NUTP will point out any such potential effects that are identified, its major effort is in developing ways of quantifying the behaviour of chemical contaminants in the environment and the associated risk to man.

3.3 THE ROLE OF MODELLING

In many endeavours, one can simply design a system and then measure the results. Thus, feedback and confirmation of performance are immediate or, at least, close at hand. In mill tailings, however, one cannot do the ultimate experiment, i.e. measure concentrations or doses 100 or 1000 years into the future. These numbers are inaccessible, yet they are the very numbers needed for decision-making. The only way to obtain the necessary quantitative predictions is by using a mathematical model. The mathematical model then becomes the bridge between what can be done in the laboratory or measured in the field today, and what one needs to know and assess many years hence.

Since predictions into the future are required, "correlative" or "empirical" modelling generally is not adequate because physical and chemical processes can change and are not contained explicitly in the model. Thus, the modelling must be built upon as much fundamental understanding as possible and has to account, in a quantitative way, for uncertainties in this understanding, in input data and in future events. In this way, assessments of the risks involved and their uncertainties are obtained.

4. PROGRAM APPROACH

4.1 THE SYSTEM

The real system contains many components and is very complex. The principal pathways are shown schematically in Figure 2. The various interacting processes fit into four major categories: source behaviour and release, physical-chemical transport of contaminants, biological uptake, and consequences such as human exposures and environmental effects. Many chemical elements are of interest, both radioactive and non-radioactive, and they can appear as different chemical species at different points along the various pathways. In addition, uncertainties exist in many parameters and further uncertainties exist in how these parameters will change with time.

4.2 THE APPROACH

Because of this complexity and uncertainty, the NUTP is taking a two-level approach to mathematical modelling shown schematically in Figure 3. The approach involves a series of separate "component models" at the detailed technical level and a "system model" linking simplified models of the components together. The component models are based as much as possible on field and laboratory observations and contain as much fundamental understanding as is available. They can be quite large and complex depending on the system. The "system model" does not attempt to couple the component models directly, but couples instead, simple models derived from the aggregate results of the more complex component models. This approach provides a very flexible structure which can readily accommodate changes in parameters and data. The reduction in complexity also allows uncertainties to be incorporated into the analysis through repetitive calculations which examine different possible combinations of parameter values.

The diversity and complexity of the real systems make it impractical if not impossible to develop single, generalized component models which will handle all possible tailings situations and questions. Thus, site-specific studies and predictions by the owners will be necessary in due course for each tailings site. However, the NUTP can strive to:

1) provide a sound scientific basis for component modelling and develop certain specific models,
2) provide a methodology and framework (i.e. system model approach) for combining component models, making long-term predictions, and answering cost-effectiveness questions, and
3) provide a general picture for certain types of Canadian tailings and various disposal options.

Validation is an important aspect of predictive model development. The component models can be validated in varying degrees by direct comparison with observations. This is less easily done for the system model whose validity depends primarily on the completeness and correctness of the component models and on a high level of computer program quality assurance in the system modelling itself to avoid numerical and programming errors. While the component areas are chosen to be as independent as possible, they are not totally independent in the real system and many interactions exist. Significant known interactions are being incorporated, of course, but unforeseen interactions are a constant hazard to the validity of the models developed. The model development work is paying particular attention to ensuring that important interactions are not overlooked.

4.3 THE PLAN

A simplified plan for the modelling component is shown in Figure 4. The top stream of generic system model development and assessment is the backbone of the modelling work. This is supported by major blocks of work in Disposal Technology, Measurements and Component Studies as previously discussed. The dashed lines on the plan show feedback from the modelling to the other major areas. The generic modelling will use hypothetical sites, but with realistic data representative of particular tailings types and systems.

Developing a methodology, however, is often not sufficient to ensure its use. To provide a focus for application to real systems, the intent is to apply the approach to the detailed assessment of demonstration sites as also shown on the plan. These assessments would be taken to the

point of evaluating the existing situation along with several alternatives for each site, but neither decisions nor recommendations would be made as to the best or preferred way to go since that step is the prerogative of the site owners. The major field studies of these sites play a key role in this demonstration plan. Such a demonstration, by those who have an interest in solving the problems that inevitably will arise, is seen to be a crucial step in the successful transfer to industry of the otherwise relatively theoretical technology being developed.

4.4 THE PROGRAM

The broad objective of the Program is to provide a scientifically credible knowledge base which will facilitate making decisions, with a known degree of confidence, on reasonable criteria and practical tailings management practices to ensure the long-term protection of man and the environment. The philosophy, approach and plan just described and aimed at meeting this goal can be summarized in the following more specific key objectives for the Program:

1) Develop the basic understanding of the chemical and physical processes operating in Canadian uranium mill tailings necessary for modelling long-term behaviour. Develop mathematical algorithms and component models for these processes and validate where possible.
2) Develop a system modelling framework to predict long-term effects and assess the cost-effectiveness of different options in reducing those effects. This approach should account explicitly for variability in system parameters and uncertainty in future events. Develop the context for using this information in decision-making.
3) Use major field studies to pilot and demonstrate the methodology, calibrate models for those specific applications, and confirm the modelling approach to the extent feasible.

4) Assemble a uranium mill tailings database and establish it in a long-term home.

As recommended in the NTPG report, the work necessary to implement the plan and achieve these objectives is divided into three project areas: Modelling, Measurements and Disposal Technology. Each area is the responsibility of a Project Manager who defines the work required in the area, consistent with the requirements of the plan and the needs of the other areas, and manages the resources available and the contracts necessary to carry it out. The mission-oriented and focussed nature of this Program has required a high degree of interaction among the three areas and a fairly selective approach to the projects and contracts undertaken.

As mentioned, the Program has been underway for effectively two years. The original plans were presented in a compendium of project plans published in early 1984 (3). Considerable progress has been made and the status of the work in each major area is summarized in the following section.

A Technical Advisory Committee regularly reviews the technical work of the Program and provides suggestions for the Program staff on specific contracts (4). The membership of the Committee is drawn from industry (five), federal government agencies (five) and the provinces (three). The Chairman of the Committee is the Director General of CANMET and the Secretary is from the National Uranium Tailings Program.

Program policy advice is provided by a Program Review Board which is chaired by the ADM, Research and Technology, EMR and has, as members, the President of the Atomic Energy Control Board, the Deputy Minister of Environment for Saskatchewan, the ADM, Planning for the Ontario Ministry of the Environment and the Director General of CANMET (as Chairman of the TAC).

Program staff and Committee Members are listed in Appendix A.

5. CONTRACTS STATUS

5.1 MODELLING

Major modelling contracts in progress or completed are listed in Table 1. The critical path item has been the system modelling in that it is a long sequence of staged development work. It is planned so that it can proceed with very crude component models initially and better models can be incorporated as they become available. The first stage of this work is completed and a sample result is discussed in Section 6.

The component modelling studies have focussed on either pulling information and modelling status together in certain areas (first five in Table 1) or developing a framework for interpreting or using the results in decision-making (last three). Further chemical and geochemical modelling is expected to follow on from these reviews. The specific contracts and report availability are discussed in more detail in Appendix C.

Some component areas have not yet received detailed attention because:

1) knowledge, models and expertise are already available e.g. surface water and groundwater flow systems, or
2) they will depend on other studies still underway e.g. sedimentation, or
3) they may not be sufficiently important to warrant major study.

The results of the system modelling will provide a quantitative means of judging the importance of the various pathways and, thus, the need for detailed modelling.

5.2 MEASUREMENTS

This section of the Program contains not only measurements in the usual field sense, but considerable fundamental research necessary to understand the field observations and the basic processes which lead to the effects observed. This discussion is therefore sub-divided into field measurements and fundamental studies. The major studies underway or completed are listed in Tables 2.1 and 2.2. The specific contracts and report availability are specified in more detail in Appendices B and C.

5.2.1 Field Measurements

Five major field programs have been undertaken, two of which are complete. Field data have been collected to assess the impact of a naturally-occurring radionuclide deposit in Newfoundland. A contract was also placed to continue a previously established monitoring program at the Nordic Main site near Elliot Lake, Ontario, and to provide a final assessment of all the collected data. Two field programs at Key Lake and Gunnar in Saskatchewan, are being handled by the Project Manager for Disposal Technology. The remaining field program which is currently underway, is at the Lacnor tailings site near Elliot Lake.

5.2.2 Fundamental Studies

The Program has awarded a number of contracts in areas of fundamental research, especially to define the source terms. However, considerably more work needs to be done to provide the understanding necessary to make reasonably confident predictions of long-term behaviour and effects. In particular, more work is required on radium geochemistry, bacteria-catalyzed reactions and chemical oxidation. Four studies are now underway to give a good scientific background in sedimentation. Two additional contracts are planned to complete the work required in this important area. An initial contract on non-radioactive contaminants is also planned.

5.3 DISPOSAL TECHNOLOGY

Generally speaking, this area is looking at all reasonable technology options from three points of view: their scientific integrity, their long-term effectiveness in reducing contaminant concentrations and their costs. The Program must also consider three classes of tailings systems with respect to time: historical (abandoned) tailings, working sites (active or inactive, but still being cared for), and future systems. Further, there are three basic types of tailings materials to be examined, low-activity acid-producing, moderate-activity neutral, and higher-activity complex mineralogy. The Program cannot undertake technology development, that being more appropriate for other jurisdictions at specific sites.

Major contracts completed or underway are listed in Table 3. Two of these contracts are measurement in nature, Gunnar and Key Lake. The impact of waste rock and the implications of cold weather were added to the Gunnar project. Field observations at Gunnar have shown that permafrost is significant and instability of the surface (wind erosion) is important.

The first phase of the Key Lake field study was completed. This project was multi-disciplinary, including mineralogy, hydrology, chemistry, meteorology and predictive modelling. The second phase of the project, which will include field and laboratory work, will be completed in 1985.

The project on Natural Materials as Barriers is considered to be important and will be underway early in 1985/86.

6. PRELIMINARY RESULTS

This section discusses results from the preliminary probabilistic assessment of uranium mill tailings. As mentioned in Section 1, this work is included to illustrate the type of predictive information expected from the Program. The purpose of the contract was to make a start on the system modelling work with the following specific goals:

1) To demonstrate a probabilistic assessment technique, applied to uranium mill tailings, and using off-the-shelf information.
2) To focus primarily on methodology and meaning. The emphasis was to be on thinking about which approaches and why.
3) To identify topics needing specific attention.
4) To demonstrate a sensitivity analysis technique.
5) To identify needs for data and/or basic understanding.

The approach was to review various methods available (four computer codes), define a test problem, benchmark one pathway, do a preliminary assessment and do a sensitivity analysis on that assessment.

The reference tailings area (hypothetical) selected is shown in Figure 5 while the pathways selected for analysis are shown in Figure 6. It is emphasized that this problem is deliberately simplified to allow attention at this stage to focus on the methods rather than be dissipated on detailing the problem. More complexity can be added later once the basic approach has been worked out.

The classical approach to modelling this type of system establishes a multiplicative chain for each pathway and adds the results for different chains at the end. Figure 7 shows the approach for a "deterministic" analysis of such a model in which single values are selected for each parameter and the model produces a single-valued result using those parameters. This result is then compared with some standard such as a regulatory criterion.

Figure 8 shows the approach for a "probabilistic" analysis of such a model in which the probability distribution of each parameter is sampled and the model produces a result for that set of parameter values. A second sample is then taken from the distribution for each parameter and a

second result is obtained. This process is repeated a number of times to build-up a frequency distribution for the calculated effect. Thus, the probabilistic approach produces a result which incorporates the natural variability and uncertainty in model parameters and gives a feel for the likelihood of a particular effect.

While this explanation is necessarily very simplified, it does give the general idea and Figure 9 shows a typical result. One hundred runs were made on the model and the relative frequency of appearance of particular values is shown. The result calculated is the dose rate at a time 200 years in the future (when the rate is relatively steady) to a person living relatively close to the tailings and living relatively extensively off the land. The mean value is about 0.1 mSv/a* which compares reasonably with deterministic values produced by other similar, but not identical, studies. The distribution shows the relative likelihood of other values.

Further analyses can be done to identify the degree of confidence in the result and how much each parameter contributes to both the mean value and the spread of the distribution. The assessment can be re-run with different sub-models for different technologies and the results compared to assess their relative effectiveness in reducing effects. Thus, the technique offers a lot of information which can be used to aid in overall decision-making and to focus the research and information gathering work on those areas which make a significant difference to the result.

7. PROGRAM STATUS

7.1 MAJOR ACHIEVEMENTS

The major achievements in the Program over its first two full years are:

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*The mSv is a unit of radiation dose. The average natural background dose rate in North America is in the order of 1 mSv/a.

1) The Program was approved and established - in the sense of funding, staffing, accommodation, contracting, management systems, procedures, etc.
2) A specific work plan was developed to meet the goals set.
3) Reviews were done or are in progress and work is underway in most technical areas.
4) Preliminary results were produced by the system model to illustrate the concept, catalyse further discussion and focus further development.
5) The major field studies are underway.
6) A database was assembled and work commenced on establishing it in a permanent home.

7.2 SCHEDULE AND FINANCES

Program resources, including salaries, are as follows (actual spending shown to 84/85; Treasury Board allocation for 85/86 and 86/87):

	82/83	83/84	84/85	85/86	86/87
K$ (84/85)	300	1200	2900	2700	1200
PY	-	7	7	7	3

Approximately 85% of the funds to date were spent on contracted-out work. In FY 84/85, the geographical split of contract funds was: Ontario 58%, Saskatchewan 22%, and other provinces 20%. By March 31, 1985, 4.4 M$ was spent by the Program. This is about 53% of the Treasury Board allocation of 8.5 M$. From the point of view of the work, about 30% of the work which logically should be done to really secure the objectives of the Program, has been completed. For perspective, it may be recalled that the NTPG report estimated 18 M$ for only slightly more work (one additional field study) (1).

8. CONCLUSION

In its first two years, the Program has made a good start towards achieving its objectives. This is due to the efforts and assistance of many people, but the staff wishes particularly to acknowledge the efforts of its first Director, Mr. V.A. Haw (retired 84/09/30) who was the major force in launching the Program and giving it its early shape.

Towards the end of the 1984/85 fiscal year the Program commenced a thorough review of its plans. The results and recommendations of completed contract work, the recommendations of the Technical Advisory Committee and the advice of the Program Review Board are all being considered in this review. The object is to use the collective wisdom of two years of experience to plan in detail the last half of this stage of the Program and to define the needs for specific work beyond the present stage to actually demonstrate and implement what has been learned and developed.

9. REFERENCES

1) "Report of the National Technical Planning Group on Uranium Mine Tailings Research", P.A. Lapp, Chairman, EMR, Ottawa, 1981.

2) "Of Acceptable Risk", William W. Lawrance, Wm. Kaufmann Inc., Los Altos, Calif., 1976.

3) "The National Uranium Tailings Program: 1982-1987". Description and Plans, CANMET Program Plans Document, Ottawa, April 1984.

4) "First Annual Report of the Technical Advisory Commmittee on the National Uranium Tailings Program" NUTP-TAC-1, CANMET, Ottawa, December 1984.

TABLES

TABLE 1

MAJOR CONTRACTS - MODELLING

CONTRACT	CONTRACTOR
GENERAL	
. Review of Existing Computer Models	- AECL/WNRE
SYSTEM MODEL DEVELOPMENT	
*. Preliminary Model Development (Phase 1)	- SENES
. Phase II	- SENES
COMPONENT STUDIES	
*. Capillary Fringe Modelling	- Waterloo
*. Kinetic Controls for Oxidation	- Waterloo
*. Geochemical Modelling of Contaminant Migration	- Waterloo
*. Algorithm Development and Modelling Review for Tailings Deposits	- IEC Beak
*. Radium Geochemistry and Modelling Review	- IEC Beak
. Discussion Paper on De Minimis Levels	- SENES
. Naturally-Occurring Levels of Radionuclides (see Measurements)	- MacLaren
. Discussion Paper on Approaches to Risk Assessment	- SENES

*Complete

TABLE 2.1

MAJOR CONTRACTS - MEASUREMENTS (Field Measurement)

CONTRACT	CONTRACTOR
FIELD PROGRAMS	
. Natural Areas - Newfoundland	- CBCL
. Lacnor	- Golder
. Nordic Main (2 complete)	- Morwijk
. Gunnar (see Technology)	
. Key Lake (see Technology)	

TABLE 2.2

MAJOR CONTRACTS - MEASUREMENTS (Fundamental Studies)

CONTRACT	CONTRACTOR
SOURCE FUNDAMENTALS	
*. Bacteria and Pyrite	- SENES
. Source Geochemistry	
ATMOSPHERIC EFFECTS	
*. Effect of Vegetation on Radon Release	- DSMA Atcon
. Dust Generation	- AER
. Radon Dispersion at Elliot Lake	- SENES
SEDIMENTATION STUDIES	
. Literature Search	- Monenco
. Biological Effects	- Monenco
. Adsorption Mechanisms	- Monenco
. Role of Organics	- Dobrocky-Seatech
BIOLOGICAL UPTAKE	
*. Zoobenthos	- SENES
*. Review of Aqueous Food Chain	- Co-op Student (U. of Sherbrooke)
MISCELLANEOUS	
. Ra-Ba Sludge	- University of Alberta
. Natural Levels	- MacLaren
. Manuals (4 complete)	- Various
. Reference Materials (5 complete)	- Various
DATABASE DEVELOPMENT	
. 7 Contracts (7 complete)	- Various

*Complete

TABLE 3

MAJOR CONTRACTS - DISPOSAL TECHNOLOGY

CONTRACT	CONTRACTOR
*. Development of Disposal Technology Component	- Melis
*. Costs of Current Disposal Technology	- Kilborn
*. Synthetic Membrane Liners	- Golder
*. Ion Exchange Radium Removal	- Melis
*. Practical Pyrite Oxidation Controls	- Hester
. Monitoring Tailings Deposition at Key Lake	- Knight & Piesold
. Gunnar Field Study - freezing - waste rock	- BBT (Sask.)
. Alternative Uranium Processing Technology	- A.H. Ross
. Natural Materials for Tailings Barriers	- Clifton

*Complete

FIGURES

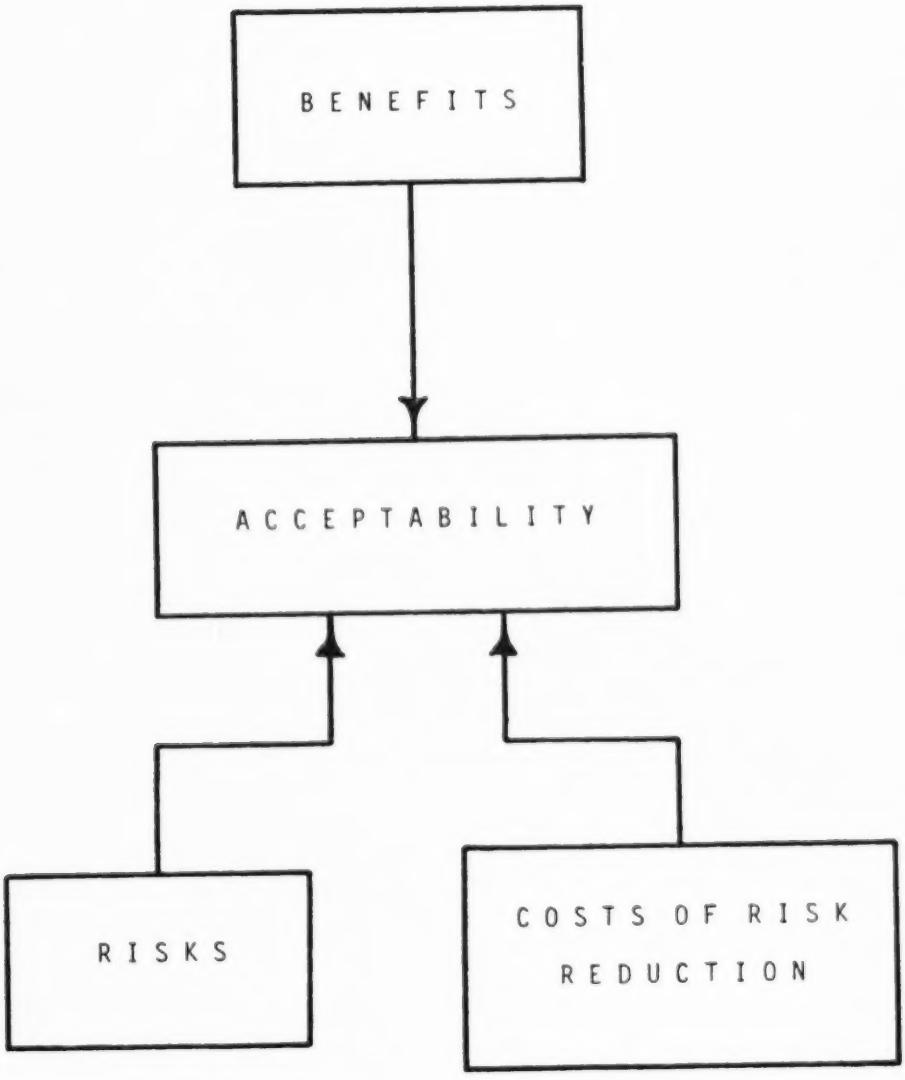


FIGURE 1 - Major Aspects of Safety Assessment

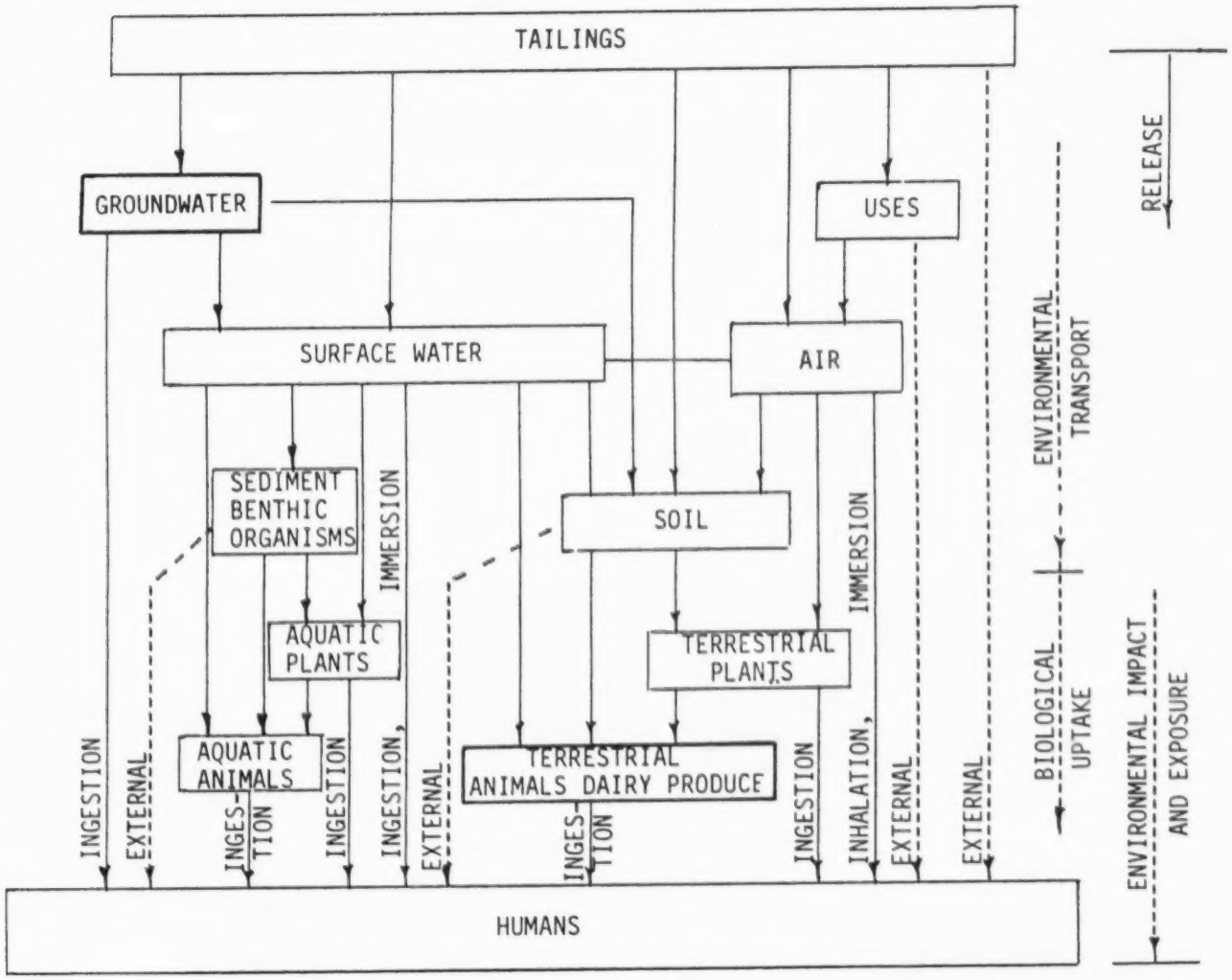


FIGURE 2 - Pathways for the Transport of Contaminants
from Tailings to Humans

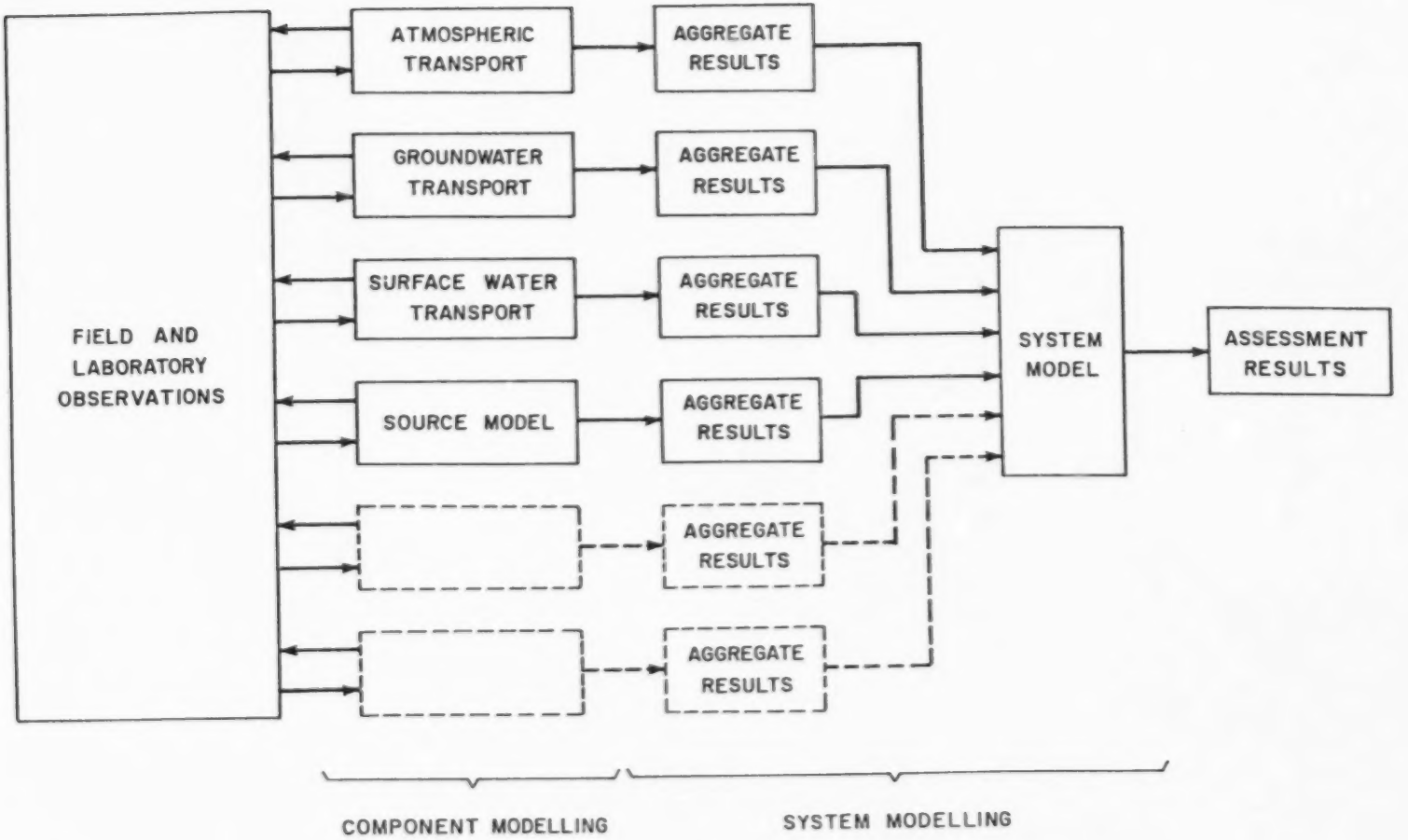


FIGURE 3 - Model Development Strategy

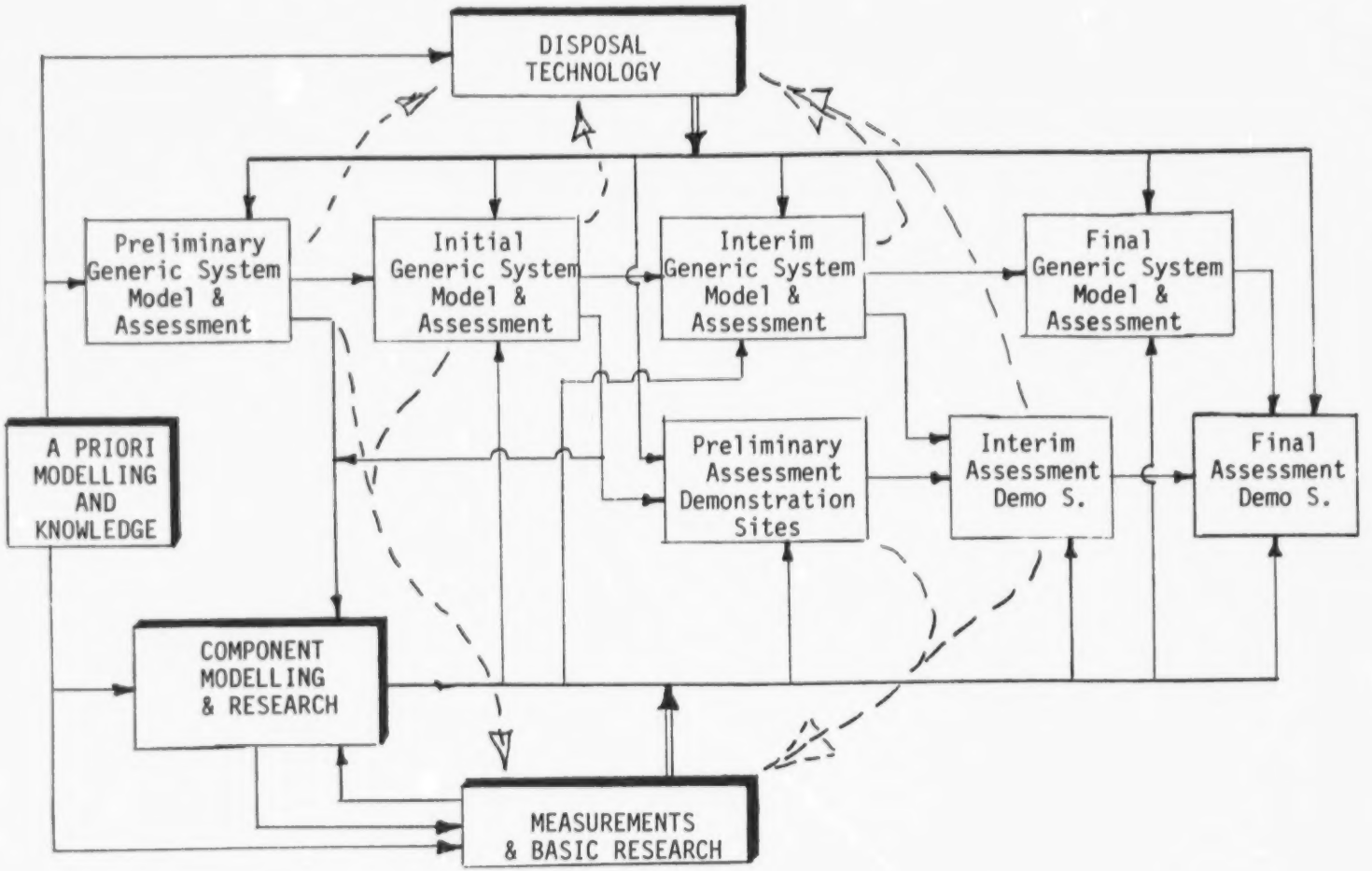
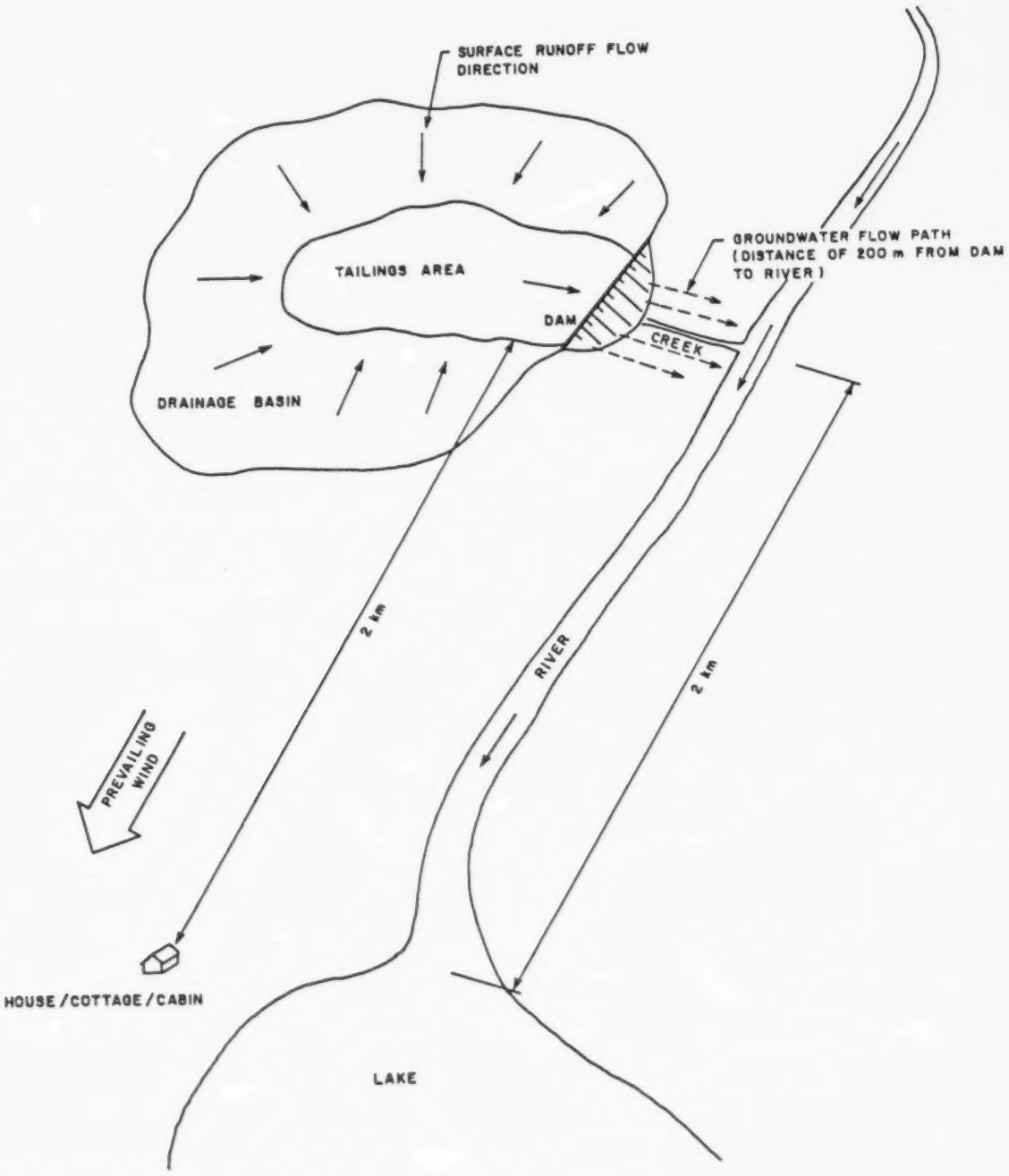

DISPOSAL TECHNOLOGY
Preliminary Generic System Model & Assessment
Initial Generic System Model & Assessment
Interim Generic System Model & Assessment
Final Generic System Model & Assessment
A PRIORI MODELLING AND KNOWLEDGE
Preliminary Assessment Demonstration Sites
Interim Assessment Demo S.
Final Assessment Demo S.
COMPONENT MODELLING & RESEARCH
MEASUREMENTS & BASIC RESEARCH

FIGURE 4 - NUTP - Systems Modelling Plan



TAILINGS AREA CHARACTERISTICS:

TAILINGS AREA SIZE - 50 ha
DRAINAGE BASIN SIZE - 150 ha
AVERAGE DEPTH OF TAILINGS - 10 m
VOLUME OF TAILINGS - 5×10^6 m^3
DEPTH TO WATER TABLE IN TAILINGS - 1 m

FIGURE 5 - Schematic Illustration of the Reference Tailings Site

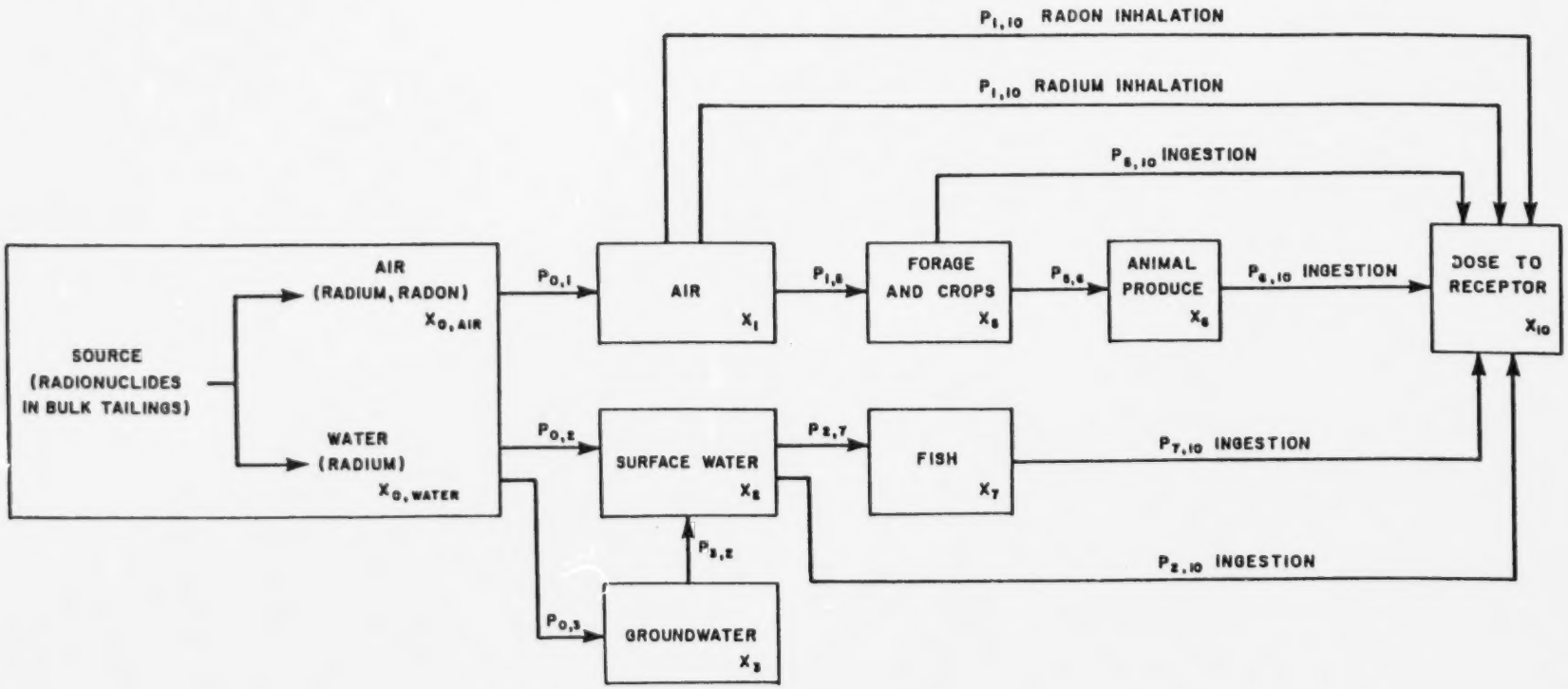


FIGURE 6 - Selected Pathways for Test Problem

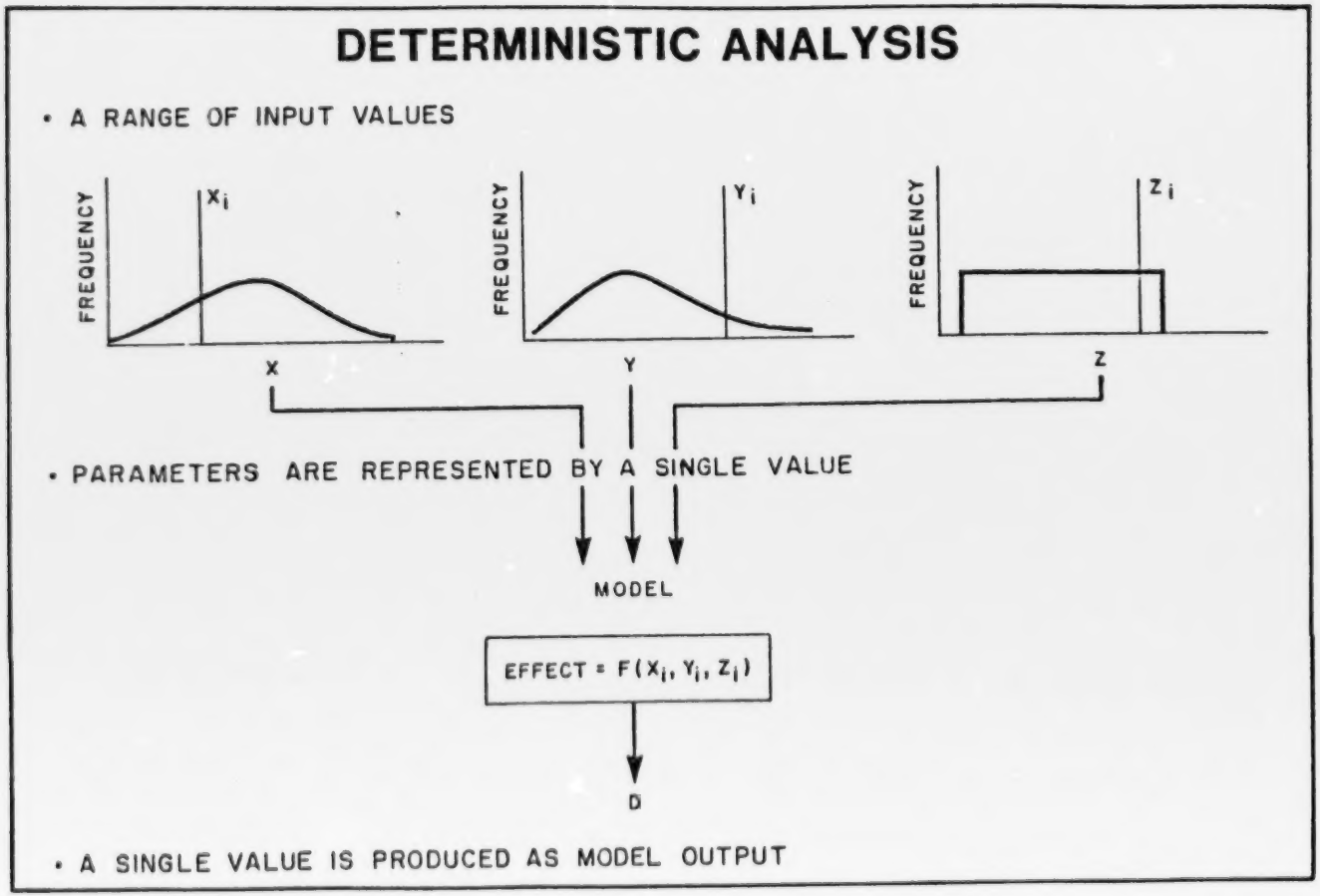


FIGURE 7 - Schematic of Approach to Deterministic Analysis

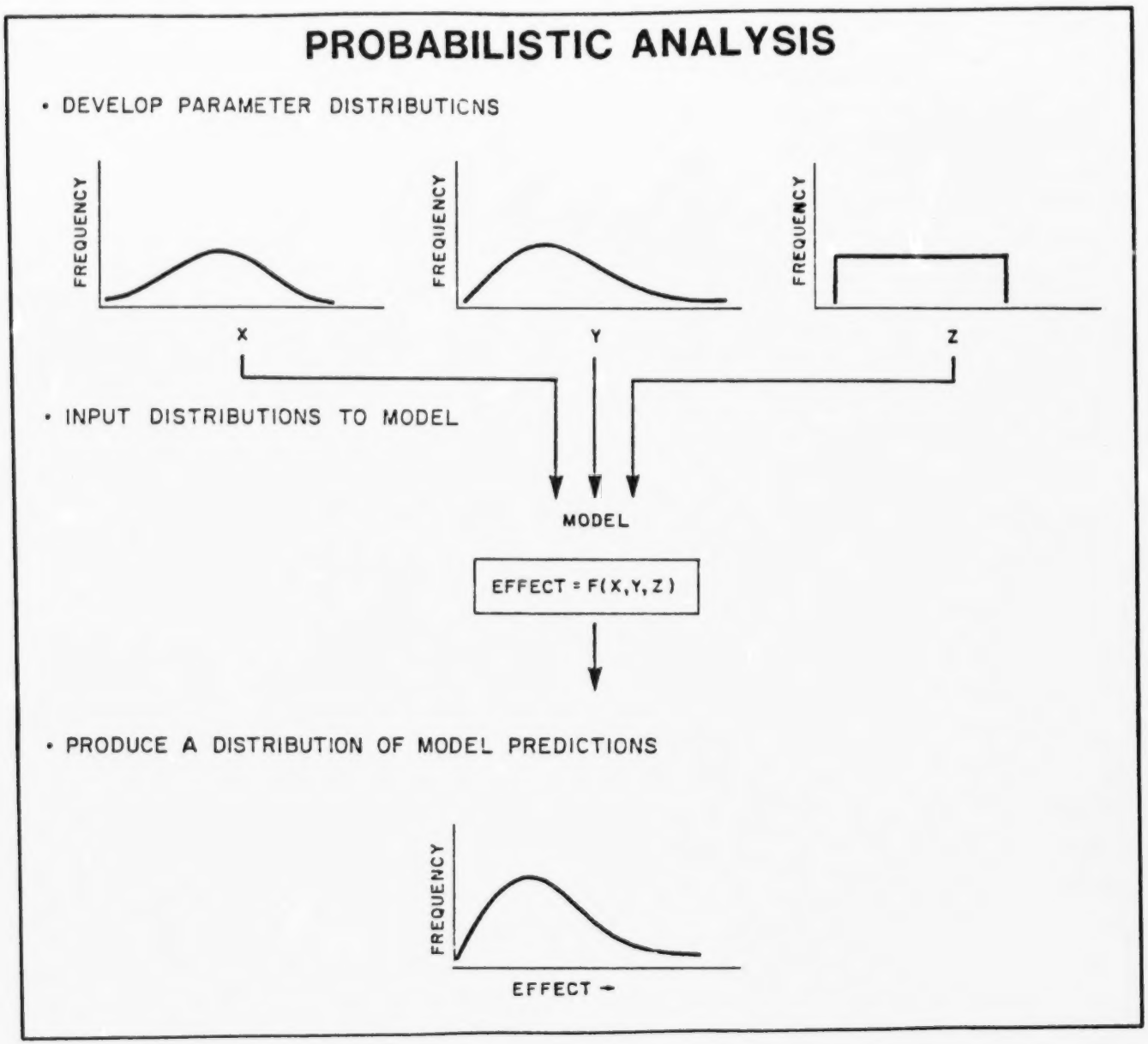


FIGURE 8 - Schematic of Approach to Probabilistic Analysis

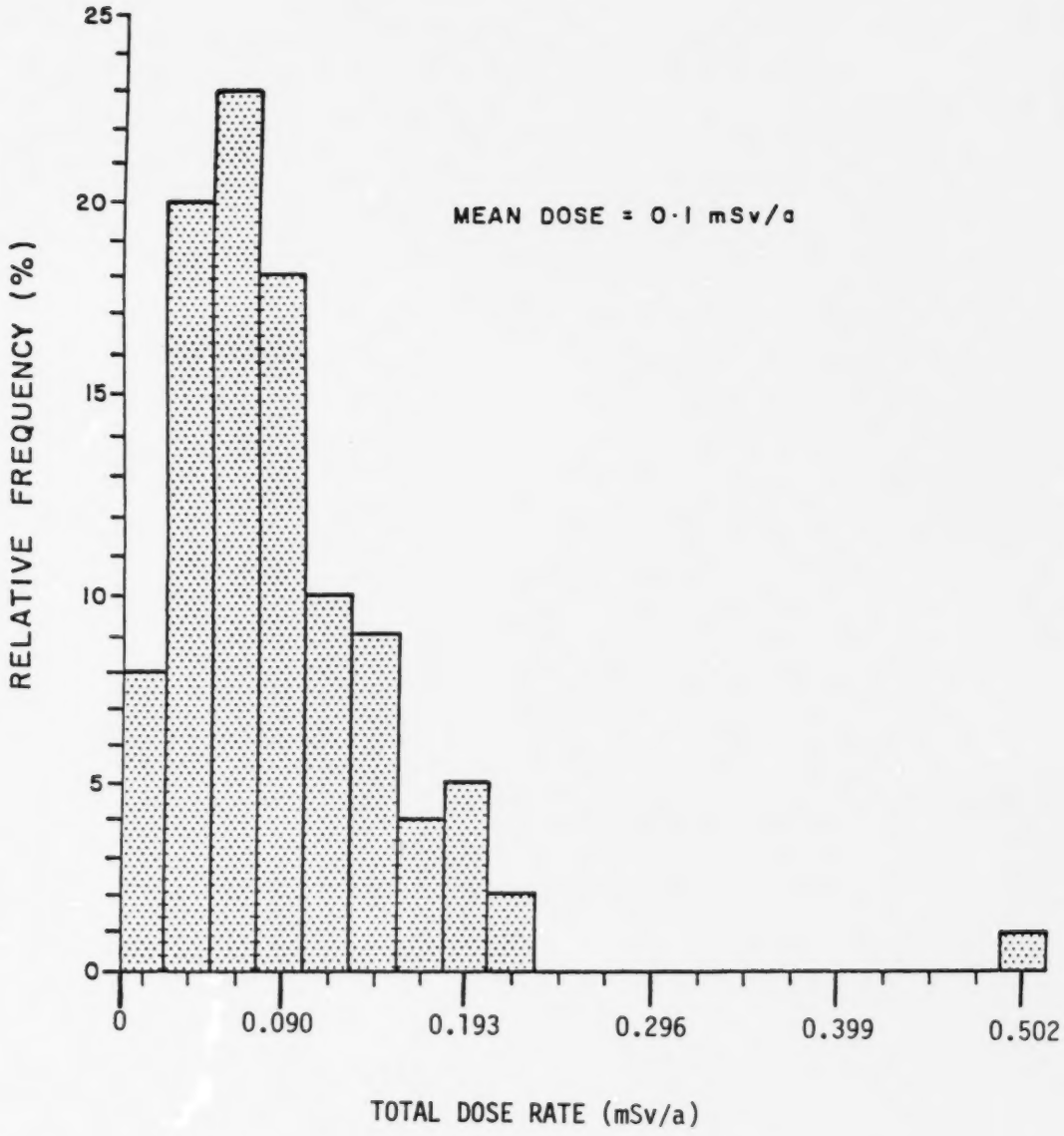


FIGURE 9 - Predicted Total Annual Dose Rate to the Reference Receptor for the Test Problem

APPENDIX A

PROGRAM INFORMATION

A.1 PROGRAM STAFF

1982 to 1985 March 31

V.A. Haw	Director to 84.9.30
W.C. Harrison	Acting Director from 84.10.01
R. John	Project Manager - Measurements
W.C. Harrison	Project Manager - Modelling
D.G. Feasby	Project Manager - Disposal Technology
G. Tremblay	Scientific Support Officer
M. Pun	Database Administrator
C. Duval-Ethier	Office Manager
C. Legault	Secretary
M. Leclair	Summer Student 1985 January/April
M. Gilbert	Summer Student 1985 January/April

A.2 PROGRAM OFFICE

Further information may be obtained from the Program office. The mailing address of the office is:

National Uranium Tailings Program
Canada Centre for Mineral and Energy Technology
555 Booth Street
Ottawa, Ontario
K1A 0G1
(613)992-6348

A.3 TECHNICAL ADVISORY COMMITTEE

MEMBERS

1983 to 1985 March 31

Dr. W.G. Jeffery	Chairman (Director General, CANMET, EMR)
Mr. G.A. Tremblay	Secretary, TAC (NUTP)
Dr. A.W. Ashbrook	Eldorado Resources Limited
Mr. K. Culver	Rio Algom Limited
Mr. C. Burton	Saskatchewan Mining Development Corporation
Dr. S.K. Ghosh	Health and Welfare Canada (to 84.12.31)
Dr. R.S. Eaton	Health and Welfare Canada (from 85.01.01)
Mr. N. Kipnis	Newfoundland Department of Mines and Energy
Mr. J. Howieson	Energy, Mines and Resources Canada
Mr. K. Bragg	Atomic Energy Control Board (to 83.11.15)
Mr. B. Zgola	Atomic Energy Control Board (from 83.11.16)
Dr. D.H. Charlesworth	Atomic Energy of Canada Limited, CRNL
Mr. J. Fry	Ontario Ministry of the Environment
Mr. J.L. Chakravatti	Denison Mines Limited
Mr. J. Scott	Environment Canada
Mr. R. Barsi	Saskatchewan Environment
Dr. B. Rosner	Key Lake Mining Corporation

A.4 PROGRAM REVIEW BOARD

MEMBERS

1984 to 1985 March 31

Dr. K. Whitham	Chairman (ADM, Research and Technology, EMR)
Mr. G.A. Tremblay	Secretary (NUTP, EMR)
Dr. W.G. Jeffery	Energy, Mines and Resources Canada, Chairman TAC
Mr. A. Carr	Saskatchewan Ministry of Environment (to Fall 1984)
Mr. P.S. van Es	Saskatchewan Ministry of Environment (from Fall 1984)
Mr. J. Jennekens	Atomic Energy Control Board
Mr. D. Redgrave	Ontario Ministry of the Environment

APPENDIX B

CANMET-NUTP REPORTS

CANMET-NUTP REPORTS

NUTP - 1 (E) or (F)	Uranium Tailings Sampling Manual	*
NUTP - 2 (E) or (F)	Uranium Tailings Reference Materials	*
NUTP - 3 (E) or (F)	Radioanalytical Methods Manual	in preparation

* Available in Canada through

Authorized Bookstore Agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Ontario
K1A 0S9

Disponible en français (F)

APPENDIX C

RESEARCH CONTRACT REPORTS

RESEARCH CONTRACT REPORTS

This appendix lists research contracts for which reports are, or will become, available. CANMET policy is that these reports are available only through a contract agent, the present agent being Micromedia Limited. This list therefore includes the Micromedia Order Number.

The list is compiled using the Contract Serial Number (XYZ8X-XXXXX) and includes contracts in place, but not yet complete. Thus, where no Micromedia Number is shown, the report was not yet complete and available through Micromedia at the time of printing.

The address for Micromedia is:

Micromedia Limited
158 Pearl Street
Toronto, Ontario
M5H 1L3

Telephone: (416)593-5211
Telex: 065-24668

Micromedia Limited should be contacted directly for price and payment information.

RESEARCH CONTRACT REPORTS - 1982-83

1. National Uranium Tailings Program - Data Standards Manual and CANUT: Users' Manual -

   Systemhouse Limited
   Micromedia Order Number: 84-0184
   CANMET (DSS) Serial Number: OSQ82-00132
   99pp/32pp/2 fiche

2. A Review of Computer Models for Assessment of the Long-Term Behaviour of Uranium Tailings -

   Atomic Energy of Canada Limited (Whiteshell)
   Micromedia Order Number: 83-3603
   CANMET (DSS) Serial Number: OSQ82-00155
   224pp/3 fiche

3. Manual for the Sampling of Uranium Mine Tailings -

   Golder Associates Limited
   Micromedia Order Number: 83-3604
   CANMET (DSS) Serial Number: OSQ82-00159
   179pp/2 fiche

   NOTE: Update and revision completed by Golder in 1983-84 under contract Serial Number OSQ83-00233.

4. A Study of Facilities Relative to Stabilization of Uranium Mill Tailings at Elliot Lake -

   Simon-Carves of Canada Limited
   Micromedia Order Number: 83-3605
   CANMET (DSS) Serial Number: OSQ82-00241
   67pp/1 fiche

5. Program Plan for the National Uranium Mine Tailings Office -

   IEC Beak Consultants Limited
   Micromedia Order Number: 83-3606
   CANMET (DSS) Serial Number: OSQ82-00242
   41pp/1 figure/1 fiche

6. Development of the Disposal Technology Research Component of the National Uranium Tailings Program -

   Lawrence A. Melis
   Micromedia Order Number: 83-3143
   CANMET (DSS) Serial Number: OSQ82-00252
   118pp/2 fiche

RESEARCH CONTRACT REPORTS - 1983-84

1. Development of an Analytical Methods Manual for the National Uranium Tailings Program -

   Monenco Consultants Limited
   Micromedia Order Number:*
   CANMET (DSS) Serial Number: OSQ83-00134

   *Manual published as NUTP-3E and NUTP-3F, see Appendix "B"

2. Acquisition and Transformation of Saskatchewan Research Council Proprietary Data by Use of a Prototype Microcomputer System for the Canadian Uranium Tailings Database (CANUT) -

   Saskatchewan Research Council
   Micromedia Order Number: 84-4734
   CANMET (DSS) Serial Number: OSQ83-00158
   241pp/3 fiche

3. A Report on the Collection of Data Relevant to the Canadian National Uranium Tailings Program -

   Systemhouse Limited
   Micromedia Order Number: 85-0602
   CANMET (DSS) Serial Number OSQ83-00225
   314pp/4 fiche

4. Assessment of the Mechanisms of Bacterially-Assisted Oxidation of Pyritic Uranium Tailings, and

   Supplementary Appendices on Literature Search Database Abstracts for the Technical Analyses of the Mechanisms of Bacterially-Assisted Pyrite Oxidation -

   SENES Consultants Limited
   Micromedia Order Number: 84-4738
   CANMET (DSS) Serial Number: OSQ83-00229
   585pp/7 fiche

5. Radium Removal from Canadian Uranium Mining Effluents by a Radium-Selective Ion-Exchange Complexer -

   Melis Consulting Engineers Limited
   Micromedia Order Number: 85-0551
   CANMET (DSS) Serial Number: OSQ83-00231
   151pp/2 fiche

6. Cost Study on Waste Management at Three Model Canadian Uranium Mines -

   Kilborn (Saskatchewan) Limited
   Micromedia Order Number: 84-3877
   CANMET (DSS) Serial Number: OSQ83-00232
   250pp/3 fiche

RESEARCH CONTRACT REPORTS - 1983-84 (Cont'd) (2)

7. Cost Study on Waste Management at Three Model Canadian Uranium Mines: Capital Cost Estimate Details -

   Kilborn (Saskatchewan) Limited
   Micromedia Order Number: 84-3878
   CANMET (DSS) Serial Number: OSQ83-00232
   112pp/2 fiche

8. Update and Revision to a Report entitled: "Manual for the Sampling of Uranium Mines Tailings" -

   Golder Associates Limited
   Micromedia Order Number: *
   CANMET (DSS) Serial Number: OSQ83-00233

   *Manual published as NUTP-1E and NUTP-1F, see Appendix "B"

9. A Study to Develop and Demonstrate Techniques for the Probabilistic Assessment of the Long-Term Effects of Uranium Mine Tailings in Canada - Phase I -

   SENES Consultants Limited
   Micromedia Order Number: 85-3434
   CANMET (DSS) Serial Number: OSQ83-00236
   251pp/3 fiche

10. Determine the Distribution of Radionuclides in Aquatic Organisms and their Environment, and Develop Transfer Coefficients - Phase I and II -

    SENES Consultants Limited
    Micromedia Order Number:
    CANMET (DSS) Serial Number: OSQ83-00241

11. Provide Data for the Atmospheric Dispersion Modelling of Radon from Uranium Mine Tailings Piles at Elliot Lake -

    SENES Consultants Limited
    Micromedia Order Number:
    CANMET (DSS) Serial Number: OSQ83-00242

12. An Experimental Investigation of Wind-Generated Suspensions of Particulate Matter from Tailings Disposal Areas -

    Atmospheric Environmental Research
    Micromedia Order Number:
    CANMET (DSS) Serial Number: 1SQ83-00268

RESEARCH CONTRACT REPORTS - 1983-84 (Cont'd) (3)

13. Study to Measure and Evaluate the Effect that Vegetation has on the Emanation Rate of Radon from a Uranium Tailings Pile -

DSMA Atcon Limited
Micromedia Order Number: 85-4584
CANMET (DSS) Serial Number: OSQ83-00273
64 pp/1 fiche

14. Practical Considerations of Pyrite Oxidation Control in Uranium Tailings -

K.D. Hester and Associates
Micromedia Order Number: 84-4739
CANMET (DSS) Serial Number: OSQ83-00278
279pp/3 fiche

15. Evaluation of Flexible Membrane Liners as Long-Term Barriers for Uranium Mill Tailings - Phase I
Volume 1 of 2 - Main Report
Volume 2 of 2 - Appendices

Golder Associates Limited
Micromedia Order Number: 84-4740
CANMET (DSS) Serial Number: OSQ83-00279
563pp/6 fiche

16. Numerical Simulation Studies of the Groundwater Discharge to Streams Discharging from the Surface of Abandoned Uranium Mill Tailings -

University of Waterloo
Micromedia Order Number: 85-3441
CANMET (DSS) Serial Number: OST83-00283
35pp/1 fiche

17. Modelling of Contaminant Migration in Acidic Groundwater Plumes at Uranium Tailings Impoundments -

University of Waterloo
Micromedia Order Number: 85-3442
CANMET (DSS) Serial Number: OST83-00284
110pp/2 fiche

18. Leachability of Radium-226 from Barium-Radium Sulphate Sludges -

University of Alberta
Micromedia Order Number:
CANMET (DSS) Serial Number: 1ST83-00325

19. Study of Kinetic Controls on Pyrite Oxidation with Application to Abandonment of Pyritic Uranium Tailings -

University of Waterloo
Micromedia Order Number: 85-3443
CANMET (DSS) Serial Number: OST83-00341
77pp/1 fiche

RESEARCH CONTRACT REPORTS - 1984-85

1. Scientific Evaluation of the Data in the Canadian Uranium Tailings Database - Phase I and II -

   IEC Beak Consultants Limited
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 0SQ84-00033

2. Descriptive Algorithm Development for Physical, Chemical and Biological Kinetics Operating in Uranium Mill Tailings -

   IEC Beak Consultants Limited
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 1SQ84-00048

3. Study of Geochemical Mechanisms Controlling Radium-226 Dissolution in Uranium Mill Tailings -

   IEC Beak Consultants Limited
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 1SQ84-00055

4. A Study of Naturally-Occurring Radionuclide Bearing Deposits at Portland Creek, Newfoundland -

   CBCL Limited
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 0SQ84-00074

5. Monitoring of Layered Uranium Tailings - Phase I -

   Knight & Piesold Limited
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 0SQ84-00085

6. Investigation of Aquatic Communities Exposed to Uranium Tailings Seepages (Elliot Lake) -

   Laurentian University
   Micromedia Order Number:
   CANMET (DSS) Serial Number: 0ST84-00190

RESEARCH CONTRACT REPORTS - 1984-85 (Cont'd) (2)

7. National Uranium Tailings Program - Gunnar Field Study -

B.B.T. Geotechnical Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: OSQ84-00195

8. National Uranium Tailings Program - Lacnor Field Study -

Golder Associates Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: OSQ84-00196

9. Development of a Discussion Paper on De Minimis (or Trivial) Levels for Contaminant Concentrations or Doses -

SENES Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: OSQ84-00198

10. Probabilistic Model Development for the Assessment of the Long-Term Effects of Uranium Mill Tailings in Canada - Phase II -

SENES Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: OSQ84-00207

11. 1984 Geochemical Study of the Acidic Contaminant Plume Near the Nordic Main Uranium Tailings Impoundment, Elliot Lake, Ontario -

Morwijk Enterprises
Micromedia Order Number: 85-4599
CANMET (DSS) Serial Number: OSQ84-00229
172 pp/2 fiche

12. Literature Review for National Uranium Tailings Program (NUTP) - Sedimentation Study -

Monenco Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: OSQ84-00297

RESEARCH CONTRACT REPORTS - 1984-85 (Cont'd) (3)

13. A Review and Assessment of the Known Naturally-Occurring Concentrations of Radionuclides -

MacLaren Plansearch Inc.
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00305

14. Approaches to Risk Assessment for Canadian Uranium Mill Tailings -

SENES Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00335

15. The Roles of Biological Organisms in the Removal of Radionuclides from Surface Waters -

Monenco Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00360

16. Speciation and Absorption/Desorption Mechanisms of Radionuclides on Lake Sediments -

Monenco Consultants Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00361

17. Alternative Uranium Ore Processing Technology -

A.H. Ross & Associates
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00414

18. Investigations on Radio-cation Speciation and its Environmental Consequences -

Dobrocky-Seatech Limited
Micromedia Order Number:
CANMET (DSS) Serial Number: 0SQ84-00416